Preliminary Survey of Indigenous, Non-indigenous and Cryptogenic Benthic Invertebrates in Burrard Inlet, Vancouver, British Columbia

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PRELIMINARY SURVEY OF INDIGENOUS, NON-INDIGENOUS AND CRYPTOGENIC BENTHIC INVERTEBRATES IN BURRARD INLET, VANCOUVER, BRITISH COLUMBIA

by

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ABSTRACT

Richoux, N.B., Levings, C.D., Lu, L. and Piercey, G.E. 2006. Preliminary survey of indigenous, non-indigenous and cryptogenic benthic invertebrates in Burrard Inlet, Vancouver, British Columbia. Can. Data Rep. Fish. Aquat. Sci. 1183: 20 pp.

In a preliminary investigation into the presence of non-indigenous invertebrates in Burrard Inlet, Vancouver, British Columbia, qualitative sampling on rocky shores, pilings and floating docks was conducted in July and August 2004. Twenty-nine sites were established, 34 samples were analysed, and 103 different taxa were identified. Data were also obtained on habitat characteristics including substrate type, salinity and temperature. Identification of polychaetes, mussels from four sites, all amphipods, isopods and patellogastropods have been confirmed by taxonomic specialists.

RESUME

Richoux, N.B., Levings, C.D., Lu, L. and Piercey, G.E. 2006. Preliminary survey of indigenous, non-indigenous and cryptogenic benthic invertebrates in Burrard Inlet, Vancouver, British Columbia. Can. Data Rep. Fish. Aquat. Sci. 1183: 20 pp.

Des échantillonnages qualitatifs sur des berges rocheuses, des empilements et des quais flottants ont été effectués en juillet et août 2004 dans le cadre d'une enquête préliminaire sur la présence éventuelle d'invertébrés non indigènes dans l'inlet Burrard, à Vancouver (Colombie-Britannique). Vingt-neuf sites ont été établis, 34 échantillons ont été analysés et 163 taxa différents ont été identifiés. Des données ont également été recueillies sur les caractéristiques des habitats, notamment le type de substrat, la salinité et la température. La présence de polychètes, de moules provenant d'autres sites, d'amphipodes, d'isopodes et de patellogastropoda a été confirmée par des taxonomistes.

INTRODUCTION

Vectors for invasion by non-indigenous marine species into coastal regions include transfer via ballast water, ship hulls and introduced aquaculture organisms (Levings et al. 2002). Habitats in Vancouver harbour and Burrard Inlet are subject to varying degrees of past and present ship traffic. We hypothesize that habitats nearest the location of the former Burrard Dry Dock (BDD), which operated from 1906 to 1992 (Anon. 2005) are characterized by the highest risk for exposure to non-indigenous species (NIS). A small dry dock operation continues adjacent to the location of the BDD. Locations near dry docks are considered high risk areas for NIS exposure as ships are routinely emptied of ballast water to raise them in the dock. In addition fouling organisms are likely to be scraped off ships' hulls during maintenance and subsequently introduced to the harbour when a ship is refloated. To test this hypothesis, benthic invertebrates were collected from boulders and floating docks along the northern coastline of Burrard Inlet to determine the natural species composition and the presence of non-indigenous and cryptogenic species. Particular attention was focused on taxa with direct development (e.g. amphipods and isopods) as species without planktonic larval stages might be expected to show a relationship with distance from a target source such as a dry dock.

With the aim of developing a comprehensive list of NIS in Vancouver harbour, a literature search was conducted to retrieve past records of NIS in this region. As noted in Levings et al. (2002) information on invertebrate communities in the harbour is almost entirely lacking, and therefore data on NIS are not readily available.

METHODS AND DATA PRESENTATIONS

Study Area Boundary

Literature records from locations east of a line from Point Atkinson to Point Grey were considered, and the boundaries of the present study extend from outer Burrard Inlet (north shore only) to outer Indian Arm (Figure 1).

Sample Collection

Twenty-nine sites were established on the north shore of the Inlet. Thirty-four non-replicated samples were collected on hard substrates from these sites between July 28 and August 18 2004 (Figure 1). Sample locations for each site were determined with a Garmin GPS 76 (Table 1).

Whenever possible, intertidal sampling protocols for baseline port surveys used by Hewitt and Martin (2001) were employed. A 0.25m x 0.25m (0.06 m^2) quadrat was used when collecting 29 of the 34 samples from above the water line. Quadrats were placed on boulders, wooden creosoted pilings, concrete slabs or rip rap and organisms removed using a household scraper. The remaining five samples (Sites 1, 19, 23, 31 and 32) were qualitative, removed by hand from under the water on floats or chains without the use of the quadrat.

Sampling was conducted on an ebbing tide at mid-tide level, and apart from the float collections, recently exposed benthic fauna were collected whenever possible. Digital photographs of the general landscape at each site and the specific quadrat placements are on file at CAER (formerly the West Vancouver Laboratory) for most of the sites.

Live samples were placed in 2L plastic jars and stored in an ice-filled cooler for subsequent transport to the laboratory.

Water temperatures were measured at the shoreline with a hand-held thermometer. Salinity samples were collected, stored on ice and determined several hours later using a refractometer. Time of day, air temperature, general weather characteristics, any details of interest regarding the site, and the distance of the quadrat to the tide line of attached *Fucus* sp. algae (when possible/applicable) were recorded for each site (Table 2).

Preliminary Sample Analysis

Upon return to the laboratory, tared sample jars were weighed to provide an approximation of the wet biomass collected at each site (Table 2). Samples were spread onto a large enamel pan and rinsed with fresh seawater. Preliminary live sorting of delicate specimens such as polychaete worms, in addition to any visible specimens of interest, were separated into smaller jars containing seawater. The remaining samples were returned to the 2L containers and topped with seawater to a known volume. Small amounts of a 33% stock solution of magnesium chloride were added to the sample jars to narcotize and relax any remaining delicate specimens. Buffered formaldehyde (37.5% solution) was added to all sample jars within 1-3 hours of the preliminary live sorting process, resulting in a 10% formalin fixative solution. Within two weeks of collection, all samples were rinsed thoroughly in fresh water over a 355µm sieve and transferred to a 70% isopropyl alcohol solution for storage.

Samples were then sorted into the various taxonomic groups using a Wild M5 dissecting microscope where appropriate. Individual organisms were not counted. Samples have been archived at CAER for future analyses or verification of identifications.

Identification of Polychaeta Specimens

All polychaetes were identified by L. Lu. Polychaetes from Site 19 were also identified by Sheila Byers, ScByers Environmental Services (202-1024 West 7th Ave., Vancouver, B.C. V6H 1B3) to provide additional verification. Samples at Site 19 were chosen for this additional step owing to its close proximity to BDD and the high diversity of specimens found.

Identification of Amphipoda, Isopoda and Mesogastropoda Specimens

All amphipods, isopods and mesogastropods were identified by Phil Hoover, Biologica Environmental Services Ltd.

Identification of *Mytilus* sp. Specimens

As species of *Mytilus* (*edulis*, *trossulus*, and *galloprovincialis*) are not readily distinguishable morphologically, two specific sampling excursions (Cates Tugs on October 21 2004; West Vancouver Lab on January 5 2005) were undertaken to obtain additional *Mytilus* individuals. These samples were identified using the GLU-5' enzyme marker (Rawson et al. 1996) by Dr. Dan Heath at the University of Windsor, Windsor, ON. At the Cates Tugs site, 10 mussels were collected from a piling near the end of the float and 10 were collected from below the water level along the side of the float. At the West Vancouver Lab site, 10 mussels were taken from a submerged tire on the float, and 10 others were collected from the styrofoam of the float. Samples were kept on ice during transport, and the mantle tissue was removed and stored in separate vials containing 100% anhydrous ethyl alcohol. The remaining tissue and shell samples were fixed in 10% formalin and stored in 70% isopropyl alcohol.

Statistical Methods

Hierarchical agglomerative clustering, based on presence/absence similarities, was used to analyse differences in community structure of the benthic invertebrates found in the survey. A group-average linked method was used in clustering, and a Tukey multi-comparison of all clusters was performed using Primer-E (Clarke and Warwick 2001). For consistency, the data set that was analysed did not include the polychaete identifications from Sheila Byers.

Literature Searches

Standard scientific bibliographic search engines (BIOSIS, ASFA, Google Scholar) were used in the literature search. Staff at the Royal BC Museum, the National Museum of Canada and the UBC herbarium were also consulted in addition to the literature collections of the authors. Computer based searches were completed up to August 31 2005.

RESULTS AND DISCUSSION

A total of 103 taxa, primarily polychaetes, amphipods and cirripeds, were found in the survey (Tables 3 and 4). Confirmation of the status of these species will require further taxonomic investigations using classical or contemporary methods. In addition, there are a large number of unidentified specimens that need detailed examination to complete the survey. Since only one NIS (*Ampithoe valida* (Amphipoda) at three sites) with direct development was found, the relationship between NIS and distance from BDD could not be tested using the present data set. Results in Table 3 (polychaetes, amphipods, isopods, and mesogastropods excepted) should be considered preliminary as they have not been verified.

Including the two hybrids of the *Mytilus* species (Table 5), a total of 16 aquatic non-indigenous and cryptogenic species have been found in Vancouver harbour (Table 6). The summarized list includes macroalgae species in addition to invertebrate taxa from

habitats that were not surveyed in the present study, such as intertidal and subtidal soft sediments, and hard substrate organisms (e.g. Pacific oyster) that were not found at the locations we sampled. By comparison, 89 species of non-indigenous algae and invertebrates were noted by Levings et al. (2002) in the entire Strait of Georgia, including the estuary of the Fraser River where numerous NIS have been found.

Results of the cluster analysis showed that invertebrate communities from the qualitative samples obtained on floating structures were separated from those on the intertidal zone and pilings. An exception was the quadrat sample from Site 2 (West Vancouver Lab floating dock) which clustered with the intertidal and piling sites. More taxa were found in the float samples (Figure 2, Group A—31 taxa) relative to the intertidal grouping (Group B—13 taxa; Group C—18 taxa; group D—15 taxa (all expressed as mean number of taxa per site), $p<0.001$ in all comparisons), therefore the floating habitats appear to be more suitable for NIS surveys owing to their inherent species richness. In addition, unlike intertidal habitats that are exposed for sampling by foot only during low to mid tide, the floating habitats are available at any time during the tide cycle for quantitative work or qualitative "directed searches" for NIS (e.g. Cohen et al. 2005).

Biologica Environmental Services (2000) also sampled the fouling community on floats or floating structures at our Site 2 (West Vancouver Laboratory) and at a Lonsdale Quay location near our Site 19. Only ten taxa were found in these two samples, although the data sets are not strictly comparable as the Biologica Environmental Services (2000) study was done during late winter when populations are reduced. One cryptogenic species, *Neanthes succinea*, was found in the Biologica Environmental Services (2000) study, but not in the present survey.

In addition to unidentified NIS, it is possible there are as yet unidentified species in Vancouver harbour, particularly of the poorly known taxa. An example is the nemertean *Callinera zhirmunskyi* recently described by Chernyshev (2002) that was found at several subtidal stations (B-49, B-38, B-48, B-3A, B-11B; see Levings et al. (2003)) in the harbour by Chernyshev (2002).

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REFERENCES

Anon. 2005. History of the Pier. City of North Vancouver Website. http://www.cnv.org/server.asp?c=2&i=113 (accessed December 13 2005).

Biologica Environmental Services. 2000. Reconnaissance survey to determine presence of marine exotic species in the Georgia Strait Basin. Unpublished document prepared for Fisheries and Oceans Canada, West Vancouver Laboratory, West Vancouver, B.C. 46 pp.

Burd, B.J. and Brinkhurst, R.O. 1990. Vancouver Harbor and Burrard Inlet Benthic Infaunal Sampling Program, October 1987. Canadian Technical Report of Hydrography and Ocean Sciences 122: 1-49.

Chernyshev, A.V. 2002. A new nemertean, *Callinera zhirmunskyi* sp.n., from the Pacific coast of Canada with a special reference to Callineridae taxonomy. Russian Journal of Marine Biology 28(2): 132-135.

Clarke, K.R. and Warwick, R.M. 2001. Change in marine communities: an approach to statistical analysis and interpretation. 2nd Edition. Plymouth, U.K.

Cohen, A.N., Harris, L.H., Bingham, B.L., Carlton, J.T., Chapman, J.W., Lambert, C.C., Lambert, G., Ljubenkov, J.C., Murray, S.N., Rao, L.C., Reardon, K. and Schwindt, E. 2005. Rapid assessment survey for exotic organisms in southern California bays and harbors, and abundance in port and non-port areas. Biological Invasions 7(6): 995-1002.

Hewitt, C.L. and Martin, R.B. 2001. Revised protocols for baseline port surveys for introduced marine species survey designs, sampling protocols and specimen handling. Centre for Research on Introduced Marine Pests. Technical Report No. 22. CSIRO Marine Research, Hobart. 46 pp.

Horiguchi, T., Li, Z., Uno, S., Shimizu, M., Shiraishi, H., Morita, M., Thompson, J.A.J. and Levings, C.D. 2003. Contamination of organotin compounds and imposex in molluscs from Vancouver, Canada. Marine Environmental Research 57:75-88.

Larson, M., Foreman, M.G.G., Levings, C.D. and Tarbotton, M.R. 2003. Dispersion of discharged ship ballast water in Vancouver harbour, Juan de Fuca Strait, and offshore of the Washington coast. Journal of Environmental Engineering and Science 2: 163-176.

Levings, C.D., Kieser, D., Jamieson, G.S. and Dudas, S. 2002. Marine and estuarine alien species in the Strait of Georgia, British Columbia. Pp. 111-131 *In* R. Claudia, P. Nantel, and E. Muckle-Jeffs (Eds). Alien Invaders in Canada's Waters, Wetlands, and Forests. Natural Resources Canada, Canadian Forest Service, Ottawa. 320 pp.

Levings, C.D., Stein, J.E., Stehr, C.M. and Samis, S.C. 2003. Introduction to the PICES practical workshop: objectives, overview of the study area, and projects conducted by the participants. Marine Environmental Research 57: 3-18.

Lindstrom, S. 1999. Literature review of introduced algae and seagrasses in the Strait of Georgia. Unpublished document prepared for Fisheries and Oceans Canada, West Vancouver Laboratory, West Vancouver, BC. 22 pp. (cited in Levings, C.D., Kieser, D., Jamieson, G.S. and Dudas, S. 2002. Marine and estuarine alien species in the Strait of Georgia, British Columbia. Pp. 111-131 *In* R. Claudia, P. Nantel and E. Muckle-Jeffs (Eds). Alien Invaders in Canada's Waters, Wetlands, and Forests. Natural Resources Canada, Canadian Forest Service, Ottawa. 320 pp.).

Rawson, P.D., Joyner, K.L., Meetze, K. and Hilbish, T.J. 1996. Evidence for intragenic recombination within a novel genetic marker that distinguishes mussels in the *Mytilus edulis* species complex. Heredity 77: 599-607.

Williams, G.L. 1999. From minutes of the *Spartina* workshop held at Canadian Wildlife Service offices, Delta, B.C. October 4 1999. Unpublished information from a contract with the Department of Fisheries and Oceans, Habitat and Enhancement Branch. (cited in Levings, C.D., Kieser, D., Jamieson, G.S. and Dudas, S. 2002. Marine and estuarine alien species in the Strait of Georgia, British Columbia. Pp. 111-131 *In* R. Claudia, P. Nantel and E. Muckle-Jeffs (Eds). Alien Invaders in Canada's Waters, Wetlands, and Forests. Natural Resources Canada, Canadian Forest Service, Ottawa. 320 pp.).

Table 1. Locations (latitudes, longitudes) of sampling sites.

Site No.	Site Name	Site Location	
		Latitude	Longitude
1	West Vancouver Lab (tire)	49° 20.404'	123° 13.980'
2	West Vancouver Lab (piling)	49° 20.404'	123° 13.980'
3	Sandy Cove	49° 20.451'	123° 13.643'
4	West Bay Park	49° 20.424'	123° 12.616'
5	31 St.	49° 20.279'	123° 12.157'
6	29 St. (boulder lower)	49° 20.123'	123° 11.741'
7	29 St. (boulder upper)	49° 20.123'	123° 11.741'
8	28 St.	49° 20.094'	123° 11.414'
9	Dundarave Park	49° 19.933'	123° 10.966'
10	23 St.	49° 19.858'	123° 10.499'
11	Argyle St.	49° 19.708'	123° 10.297'
12	John Lawson Park	49° 19.582'	123° 09.619'
13	Ambleside Pier West	49° 19.563'	123° 09.281'
14	Ambleside Park	49° 19.305'	123° 08.914'
15	Lions Gate Bridge	49° 19.013'	123° 08.223'
16	Mckay Creek	49° 18.636'	123° 06.515'
17	Harborside Place	49° 18.791'	123° 05.610'
18	Lonsdale Quay	49° 18.677'	123° 05.100'
19	Cates Tugs (float) (immediately adjacent to BDD location)	49° 18.554'	123° 04.933'
20	Cates Tugs (piling) (immediately adjacent to BDD location)	49° 18.554'	123° 04.933'
21	Pier 94	49° 18.315'	123° 04.334'
22	Harborview Park	49° 17.936'	123° 02.374'
23	Lynnwood Marina (float)	49° 17.920'	123° 01.524'
24	Lynnwood Marina (piling)	49° 17.920'	123° 01.524'
25	ERCO	49° 17.878'	123° 00.659'
26	Maplewood West	49° 18.130'	123° 00.191'
27	Maplewood Mid	49° 18.291'	122° 59.842'
28	Maplewood East	49° 18.467'	122° 59.637'
29	Dollarton Hwy. near Ellis St.	49° 18.493'	122° 59.144'
30	Dollarton Shipyard	49° 18.193'	122° 58.031'
31	Cates Park Site 1 (float)	49° 18.079'	122° 57.598'
32	Cates Park Site 1 (chain)	49° 18.079'	122° 57.598'
33	Cates Park Site 2	49° 18.065'	122° 57.503'
34	Cates Park Site 3	49° 18.097'	122° 57.264'

Table 2. Site sampling dates and physical parameters. '–' indicates no weight obtained. The distance from the sample site to the lowest extent of the *Fucus* sp. boundary is also given for intertidal locations.

Site No.	Site Name	Date (2004)	Time (DST)	Substrate	Sample Wet Wt (g)	Weather
1	West Vancouver Lab (tire)	Aug 17	1120	tire under float	1772	calm day
2	West Vancouver Lab (float)	Aug 17	1120	float	2714	calm day
3	Sandy Cove	Jul 28	0716	boulder	–	muggy, choppy ocean, overcast
4	West Bay Park	Jul 28	0640	boulder	–	choppy ocean, clear
5	31 St.	Aug 4	1227	boulder	1501	overcast, warm, calm
6	29 St. (boulder lower)	Aug 11	0709	boulder-lower level	123	clear, calm, warm
7	29 St. (boulder upper)	Aug 11	0709	boulder-upper level	1003	clear, calm, warm
8	28 St.	Aug 4	1156	boulder	1783	overcast, warm, calm
9	Dundarave Park	Jul 30	0756	boulder	2242	sunny, choppy
10	23 St.	Aug 11	0638	boulder	1405	clear, calm, warm
11	Argyle St.	Aug 4	1115	boulder	1395	overcast, warm, calm
12	John Lawson Park	Jul 30	0728	piling	2169	sunny, calm
13	Ambleside Pier West	Aug 13	0643	piling	2187	overcast, warm, some waves
14	Ambleside Park	Jul 30	0646	boulder	1174	sunny, calm
15	Lions Gate Bridge	Aug 13	0711	boulder	2338	overcast, warm, some waves
16	Mckay Creek	Aug 3	1230	concrete	433	light rain, overcast, calm
17	Harborside Place	Aug 3	1142	concrete	385	light rain, overcast, calm
18	Lonsdale Quay	Jul 29	0710	riprap	–	warm, muggy, overcast
19	Cates Tugs (float)	Aug 18	1245	float	1088	sunny, clear
20	Cates Tugs (piling)	Aug 18	1245	piling	2192	sunny, clear
21	Pier 94	Jul 29	0756	boulder	–	warm, muggy, overcast
22	Harborview Park	Aug 3	1038	boulder	1098	light rain, overcast, calm
23	Lynnwood Marina (float)	Aug 18	1145	float	960	sunny, clear
24	Lynnwood Marina (piling)	Aug 18	1145	piling	1909	sunny, clear
25	ERCO	Aug 13	0842	piling	1627	overcast, warm, some waves
26	Maplewood West	Aug 5	1254	boulder	438	clear, calm, warm
27	Maplewood Mid	Aug 5	1327	piling	3172	clear, calm, warm
28	Maplewood East	Aug 18	1100	boulder	1130	sunny, clear
29	Dollarton Hwy. near Ellis.	Aug 12	0743	boulder	762	clear, calm, warm
30	Dollarton Shipyard	Aug 12	0709	boulder	623	clear, calm, warm
31	Cates Park Site 1 (float)	Aug 17	0945	foam float	1032	calm, rain earlier
32	Cates Park Site 1 (chain)	Aug 17	0945	chain under float	967	calm, rain earlier
33	Cates Park Site 2	Aug 17	1000	boulder	1320	calm, rain earlier
34	Cates Park Site 3	Aug 17	1020	boulder	1155	calm, rain earlier

Table 2. (continued)

Site No.	Salinity (psu)	Air Temp (C)	Water Temp (C)	*Fucus* Line (m)	Notes
1	22	19	20	n/a	mussels dominant
2	22	19	20	n/a	mussels dominant
3	24	17	16	7.4	mussels, *Fucus*, some sand
4	24	16	15	7.4	mussels, *Fucus*
5	22	20	18	6.2	mussels, barnacles
6	19	17	18	19.3	barnacles, green algae, sample taken at the level of seastars
7	19	17	18	19.3	barnacles, green algae, sample taken high on the rock far above the tide line
8	22	20	18	7.8	mussels, barnacles, *Fucus*
9	25	18	16	4.5	mussels, some barnacles
10	21	17	18	8.8	mussels, barnacles
11	22	21	18	3.3	mussels, barnacles
12	26	18	16	1.3	mussels, small barnacles
13	17	18	18	2.7	mussels, barnacles
14	24	18	17	2.3	mussels, *Fucus*, barnacles
15	25	18	17	5	mussels, barnacles
16	28	19	16	3.2	barnacles, *Fucus*, mussels, red algae
17	22	18	16	2.6	barnacles, red algae, snails, varnish clam shells in area
18	24	20	15	3.8	*Fucus*, brown algae, barnacles, snails, limpets
19	25	20	17	n/a	mussels, anemones
20	25	20	17	n/a	mussels
21	28	15	13	4.8	*Fucus*, brown algae, small mussels, scunge, near culvert and road runoff
22	9	22	17	2.6	*Fucus*, mussels, barnacles
23	25	20	16	n/a	mussels, feather duster worms nearby
24	25	20	17	n/a	mussels, feather duster worms nearby
25	26	18	17	n/a	mussels, barnacles
26	27	19	17	1.2	*Fucus*, barnacles, red algae
27	27	19	20	n/a	mussels, barnacles
28	29	20	20	n/a	
29	28	16	15	7	barnacles, *Fucus*
30	28	16	15	3.5	*Fucus*, barnacles
31	30	18	15	n/a	mussels
32	30	18	15	n/a	mussels
33	29	18	16	13.8	mussels
34	27	18	16	13.7	barnacles, *Fucus*

Table 3. Presence (+) and absence of taxa recorded in the survey. See Table 5 for confirmed identifications of *Mytilus* sp.

Taxa	Site Number 1	2	3	4	5	6	7	8	9	10	11
PORIFERA											
CNIDARIA: HYDROZOA											
Clytia sp.	+										
Obelia dichotoma (Linnaeus, 1758)	+										
unidentified	+										
PLATYHELMINTHES		+			+				+	+	+
NEMERTEA											
Amphiporus cruentatus Verrill, 1879 or *imparispinosus* Griffin, 1898	+	+			+		+	+	+	+	+
Emplectonema gracile (Johnston, 1837)		+	+	+	+	+		+	+	+	+
unidentified			+	+	+			+	+	+	+
NEMATODA	+		+	+	+			+	+	+	+
ANNELIDA: POLYCHAETA											
ANNELIDA: POLYCHAETA: CAPITELLIDA											
Capitella capitata complex (Fabricius, 1780)											
ANNELIDA: POLYCHAETA: OPHELIIDA											
Armandia brevis (Moore, 1906)											
Ophelina breviata (Ehlers, 1913)											
ANNELIDA: POLYCHAETA: PHYLLODOCIDA											
Brania brevipharyngea Banse, 1972											
Eteone californica Hartman, 1936			+								
Eulalia aviculiseta Hartman, 1936	+	+									
Exogone (Exogone) dwisula Kudenov and Harris, 1905											
Harmothoe imbricata (Linnaeus, 1767)	+										
Micropodarke dubia (Hessle, 1925)											
Nereis vexillosa Grube, 1851	+	+	+		+						+
Nereis zonata Malmgren, 1867											
Nereis sp.											
Platynereis cf bicanaliculata (Baird, 1863)	+										
Podarke pugettensis Johnson, 1901											
Procerae sp.	+										
Pterocirrus montereyensis (Hartman, 1936)											
Sphaerosyllis californiensis Hartman, 1966											
Syllis elongata Johnson, 1901		+									
Typosyllis adamanteus (Treadwell, 1914)		+	+	+	+	+	+	+	+		+
Typosyllis cf fasciata (Malmgren, 1867)											
Typosyllis cf pulchra (Berkeley and Berkeley, 1938)	+										
ANNELIDA: POLYCHAETA: SABELLIDA											
Potamilla reniformis (Leukart, 1849)											
ANNELIDA: POLYCHAETA: SPIONIDA											
Boccardia columbiana Berkeley, 1927			+								
Dipolydora socialis (Schmarda, 1861)											
Polydora cornuta Bosc, 1802		+									
Polydora sp.											
Scoletepis squamata (O.F. Muller, 1806)			+								

Table 3. (continued)

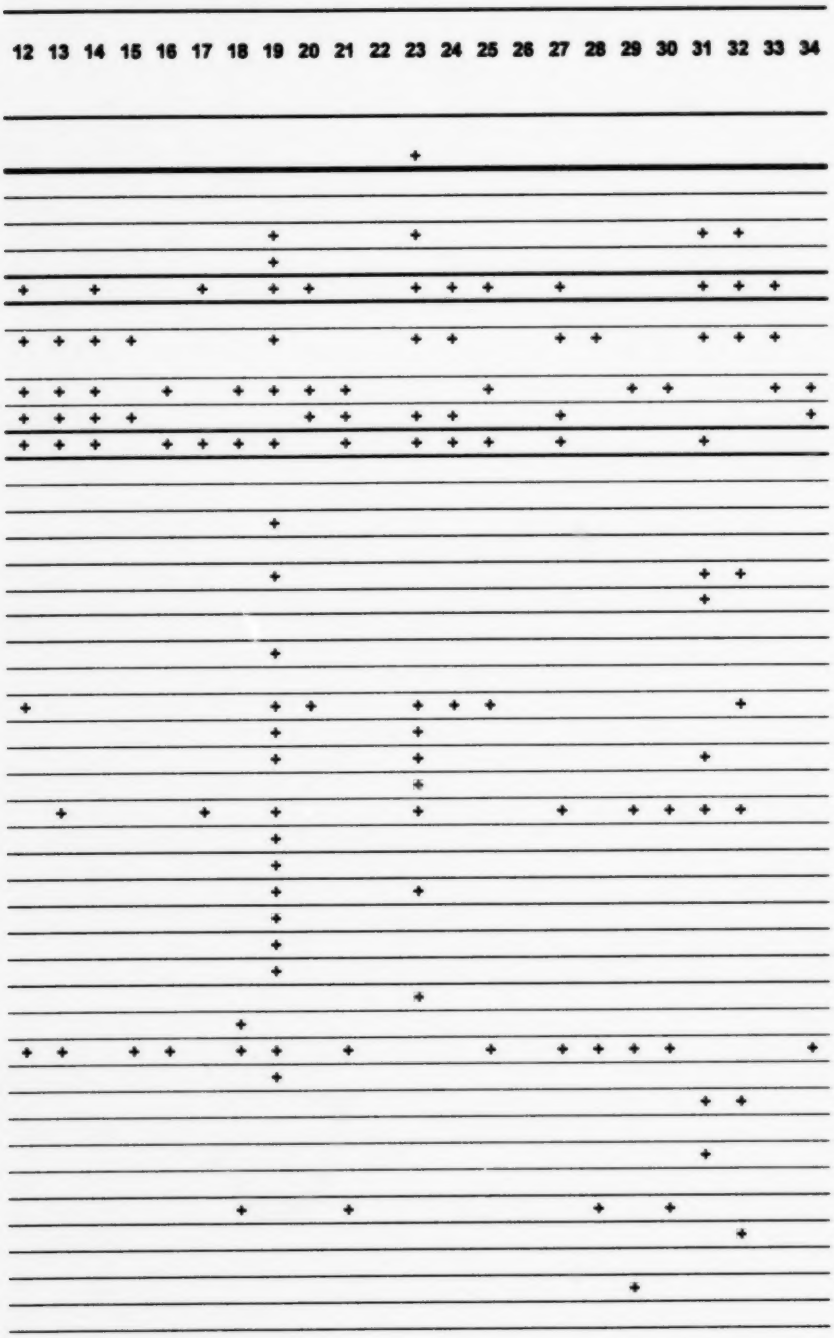

Table 3. (continued)

Taxa	Site Number	1	2	3	4	5	6	7	8	9	10	11
ANNELIDA: POLYCHAETA: TEREBELLIDA												
Asabellides sibirica (Wiren, 1883)		+		+	+	+	+		+	+	+	+
ANNELIDA: OLIGOCHAETA												
MOLLUSCA: GASTROPODA: NUDIBRANCHIA												
Hermissenda crassicornis (Eschscholtz, 1831)			+									
Onchidoris bilamellata (Linnaeus, 1767)		+										
Nudibranchia larvae												
MOLLUSCA: GASTROPODA: MESOGASTROPODA												
Littorina scutulata Gould, 1849		+	+	+	+	+	+	+	+	+	+	+
Odostomia sp.												
small Turbinidae snail												
unidentified		+									+	
MOLLUSCA: GASTROPODA: PATELLOGASTROPODA												
Lottia ochracea (Dall, 1871)							+					
Lottia pelta (Rathke, 1833)				+	+	+	+	+	+	+	+	+
Lottia indet.												
MOLLUSCA: BIVALVIA												
Mytilus (Mytilus) trossulus Gould, 1850		+	+	+	+	+		+	+	+	+	+
Mytilidae indet.				+								+
ARTHROPODA: PSEUDOSCORPIONIDA												
ARTHROPODA: ARARIDA					+	+		+				+
ARTHROPODA: CRUSTACEA: COPEPODA												
Cyclopoida		+										
Harpacticoida		+		+	+	+	+	+	+		+	+
ARTHROPODA: CRUSTACEA: OSTRACODA		+		+	+	+						+
ARTHROPODA: CRUSTACEA: CIRRIPEDIA												
Balanus crenatus Bruguiere, 1789		+	+	+	+	+	+	+	+	+		
Balanus glandula Darwin, 1854						+				+	+	+
Chthamalus dalli Pilsbry, 1916							+	+				
Balanomorpha indet.												
barnacle nauplii												
ARTHROPODA: CRUSTACEA: ISOPODA												
Gnorimosphaeroma oregonense (Dana, 1853)		+		+		+	+	+				+
Idotea (Pentidotea) wosnesenskii (Brandt, 1851)		+			+	+			+			
Ligia (Ligia) pallasii Brandt, 1833												
Munna sp.												
unidentified												
ARTHROPODA: CRUSTACEA: AMPHIPODA: GAMMARIDAE												
Americorophium brevis (Shoemaker, 1949)												
Americorophium spinicorne (Stimpson, 1857)									+			
Americorophium sp.												
Ampithoe valida S.I. Smith, 1873		+			+							
Ampithoe sp.		+										

Table 3. (continued)

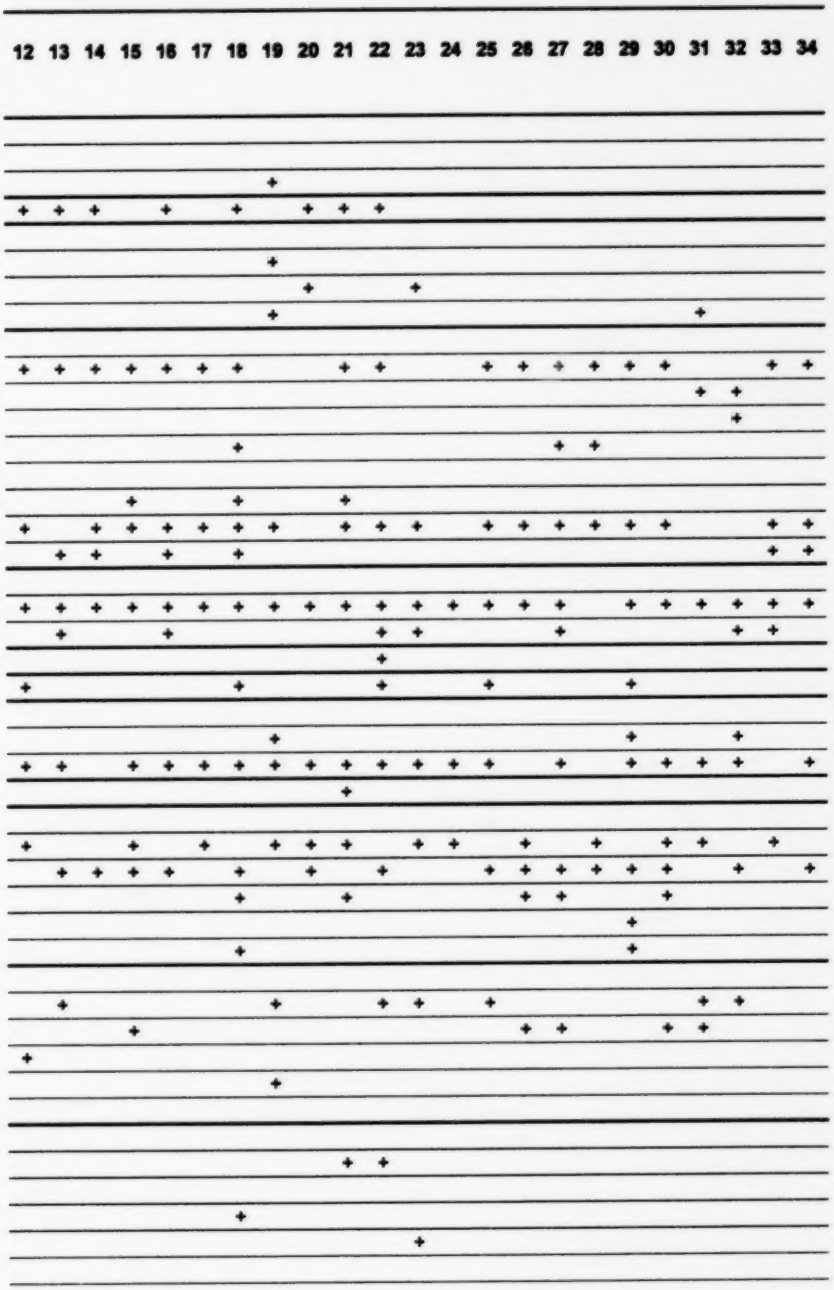

Table 3. (continued)

Taxa	Site Number	1	2	3	4	5	6	7	8	9	10	11
Ampithoidae indet.					+							
Aoroides columbiae A.O. Walker, 1898												
Eogammarus oclairi Bousfield, 1979												
Gammaridae indet.												
Gnathopleustes pachychaetus Bousfield and Hendrycks, 1995	+											
Jassa staudei Conlan, 1990	+											
Monocorophium carlottensis Bousfield and P.M. Hoover, 1997								+	+		+	
Monocorophium sp.							+	+				
Oligochinus lighti J.L. Barnard, 1969				+								
Parapleustes gracilis Buchholz, 1874												
Pleustidae indet.												
Ptilohyale plumulosa (Stimpson, 1857)	+					+	+	+	+		+	+
ARTHROPODA: CRUSTACEA: AMPHIPODA: CAPRELLIDAE												
Caprella alaskana Mayer, 1903												
Caprella laeviuscula Mayer, 1903												
Caprellidae indet.	+											
Metacaprella anomala (Mayer, 1903)												
ARTHROPODA: CRUSTACEA: DECAPODA: ANOMURA												
Pagurus hirsutiusculus (Dana, 1851)					+							
ARTHROPODA: CRUSTACEA: DECAPODA: BRACHYURA												
Cancer magister Dana, 1852	+	+										
Hemigrapsus oregonensis (Dana, 1851)		+			+	+			+			+
BRYOZOA												
Alcyonidium polyoum Hassall, 1841												
Alderina brevispina (O'Donoghue and O'Donoghue, 1926)	+											
Bowerbankia gracilis Leidy, 1855												
Celleporella hyalina (Linnaeus, 1767)	+										+	
Membranipora membranacea (Linnaeus, 1767)	+											
ECHINODERMATA: ASTEROIDEA												
Pisaster ochraceus (Brandt, 1835)												
ECHINODERMATA: ECHINOIDEA												
Strongylocentrotus droebachiensis (O.F. Muller, 1776)												
Miscellaneous												
MOLLUSCA: BIVALVIA - clam shells				+								
ARTHROPODA: DIPTERA: CHIRONOMIDAE		+	+		+	+	+	+	+	+	+	
ARTHROPODA: DIPTERA					+			+	+	+	+	+
algae - *Fucus* sp.								+				+
algae - other	+		+	+	+	+			+	+	+	+
MONOCOTYLEDONEAE (sea grasses)												
eggs												

Table 3. (continued)

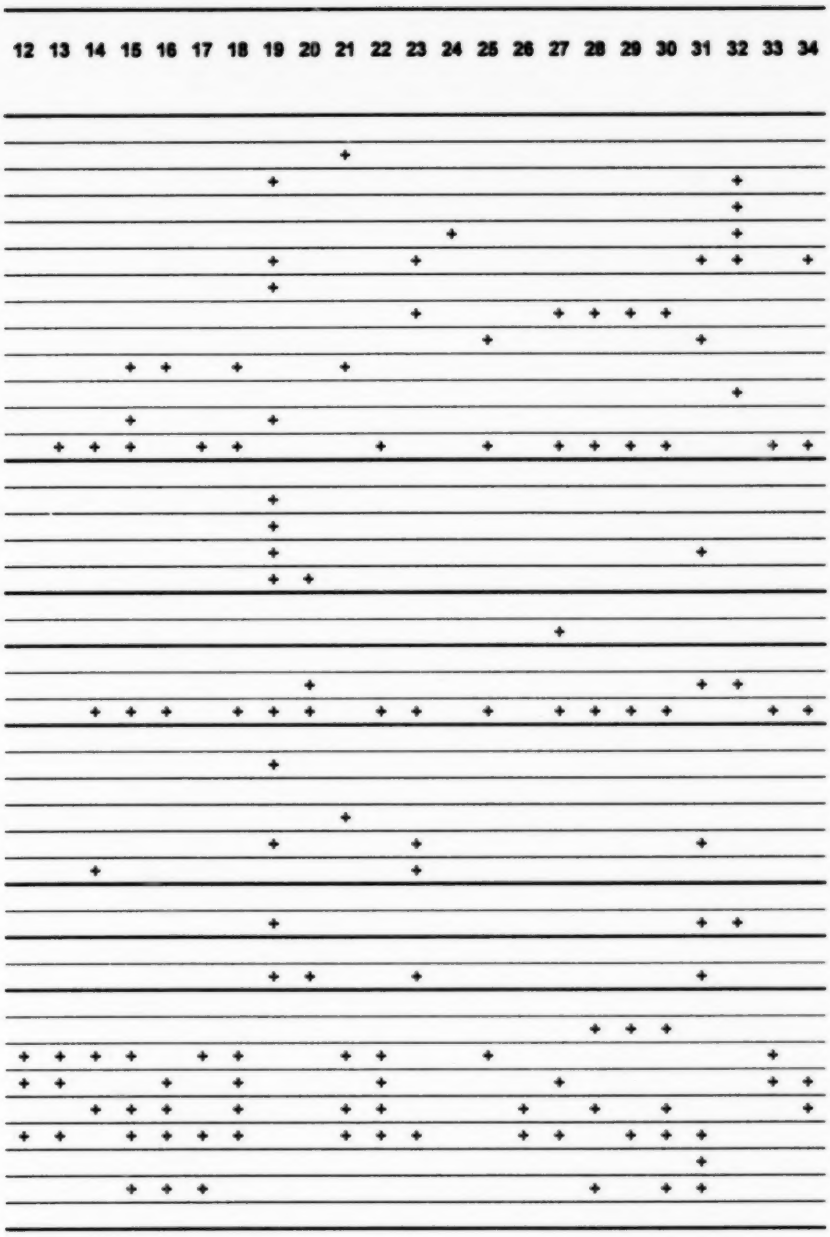

Table 4. Number of invertebrate taxa found in the Burrard Inlet survey categorized by major taxonomic group.

Taxa	No. of Taxa
Porifera	1
Cnidaria: Hydrozoa	3
Platyhelminthes	1
Nemertea	3
Nematoda	1
Annelida: Polychaeta: Capitellida	1
Annelida: Polychaeta: Opheliida	2
Annelida: Polychaeta: Phyllodocida	18
Annelida: Polychaeta: Sabellida	1
Annelida: Polychaeta: Spionida	5
Annelida: Polychaeta: Terebellida	1
Annelida: Oligochaeta	1
Mollusca: Gastropoda: Nudibranchia	3
Mollusca: Gastropoda: Mesogastropoda	4
Mollusca: Gastropoda: Patellogastropoda	3
Mollusca: Bivalvia	2
Arthropoda: Pseudoscorpionida	1
Arthropoda: Ararida	1
Arthropoda: Crustacea: Copepoda	2
Arthropoda: Crustacea: Ostracoda	1
Arthropoda: Crustacea: Cirripedia	5
Arthropoda: Crustacea: Isopoda	5
Arthropoda: Crustacea: Amphipoda: Gammaridae	17
Arthropoda: Crustacea: Amphipoda: Caprellidae	4
Arthropoda: Crustacea: Decapoda: Anomura	1
Arthropoda: Crustacea: Decapoda: Brachyura	2
Bryozoa	5
Echinodermata: Asteroidea	1
Echinodermata: Echinoidea	1
Miscellaneous	7

Table 5. Identification of *Mytilus* sp. hybrids using GLU-5' enzyme marker (Rawson 1996). Samples from Sites 1 (West Vancouver Lab (tire)), 19 (Cates Tugs (float)), and 20 (Cates Tugs (piling)). Mg = *Mytilus galloprovincialis*; Mt = *Mytilus trossulus*; Me = *Mytilus edulis*. Mt/Mg and Mt/Me indicate hybrids of *M. trossulus* with *M. galloprovincialis* and *M. edulis*, respectively.

Site No.	Site Name	Sample No.	Sample Date	Identification	Shell Length (cm)
20	Cates Tugs (piling)	1	Oct 21 04	Mt	4.7
20	Cates Tugs (piling)	2	Oct 21 04	Mt	3.5
20	Cates Tugs (piling)	3	Oct 21 04	Mt	4.0
20	Cates Tugs (piling)	4	Oct 21 04	Mt	4.1
20	Cates Tugs (piling)	5	Oct 21 04	Mt	4.5
20	Cates Tugs (piling)	6	Oct 21 04	Mt	4.5
20	Cates Tugs (piling)	7	Oct 21 04	Mt	4.2
20	Cates Tugs (piling)	8	Oct 21 04	Mt/Mg	4.2
20	Cates Tugs (piling)	9	Oct 21 04	Mt	3.0
20	Cates Tugs (piling)	10	Oct 21 04	Mt	3.6
19	Cates Tugs (float)	11	Oct 21 04	Mt	4.2
19	Cates Tugs (float)	12	Oct 21 04	Mt	5.9
19	Cates Tugs (float)	13	Oct 21 04	Mt	3.8
19	Cates Tugs (float)	14	Oct 21 04	Mt	4.3
19	Cates Tugs (float)	15	Oct 21 04	Mt/Me	3.6
19	Cates Tugs (float)	16	Oct 21 04	Mt	4.5
19	Cates Tugs (float)	17	Oct 21 04	Mt	4.0
19	Cates Tugs (float)	18	Oct 21 04	Mt/Me	5.1
19	Cates Tugs (float)	19	Oct 21 04	Mt	4.5
19	Cates Tugs (float)	20	Oct 21 04	Mt	5.5
2	West Vancouver Lab (float)	21	Jan 05 05	Mt	3.5
2	West Vancouver Lab (float)	22	Jan 05 05	Mt	5.4
2	West Vancouver Lab (float)	23	Jan 05 05	Mt	4.4
2	West Vancouver Lab (float)	24	Jan 05 05	Mt	4.8
2	West Vancouver Lab (float)	25	Jan 05 05	Mt	4.8
2	West Vancouver Lab (float)	26	Jan 05 05	Mt	4.2
2	West Vancouver Lab (float)	27	Jan 05 05	Mt	3.0
2	West Vancouver Lab (float)	28	Jan 05 05	Mt	4.0
2	West Vancouver Lab (float)	29	Jan 05 05	Mt	3.9
2	West Vancouver Lab (float)	30	Jan 05 05	Mt	4.1
1	West Vancouver Lab (tire)	31	Jan 05 05	Mt	4.0
1	West Vancouver Lab (tire)	32	Jan 05 05	Mt	3.5
1	West Vancouver Lab (tire)	33	Jan 05 05	Mt	4.3
1	West Vancouver Lab (tire)	34	Jan 05 05	Mt	2.7
1	West Vancouver Lab (tire)	35	Jan 05 05	Mt	2.9
1	West Vancouver Lab (tire)	36	Jan 05 05	Mt	4.2
1	West Vancouver Lab (tire)	37	Jan 05 05	Mt	4.2
1	West Vancouver Lab (tire)	38	Jan 05 05	Mg/Mt	3.9
1	West Vancouver Lab (tire)	39	Jan 05 05	Mt	4.1
1	West Vancouver Lab (tire)	40	Jan 05 05	Mt	3.4

Table 6. Preliminary list of non-indigenous and cryptogenic species reported from Vancouver harbour in present survey and the literature. '*' indicates cryptogenic species.

Species	Group	Common Name	Recorded Locations	Reference
Antithamnionella spirographidis (Schiffner) E.M. Wollaston, 1968	Algae	None	Stanley Park	Lindstrom, 1999 (record also in UBC herbarium)
Sargassum muticum (Yendo) Fensholt	Algae	Japanese weed	West Vancouver, North Vancouver floats; likely widespread	Present study; Lindstrom 1999 (records in UBC herbarium)
Tubificoides benedii (d'Udekem, 1855)	Oligochaete	None	Subtidal in central Vancouver harbour	Burd and Brinkhurst 1990
**Boccardia columbiana* Berkeley, 1927	Polychaete	None	See Table 3	Present study
**Nereis zonata* Malmgren, 1867	Polychaete	None	See Table 3	Present study
**Platynereis cf bicanaliculata* (Baird, 1863)	Polychaete	None	See Table 3	Present study
Polydora cornuta Bosc, 1802	Polychaete	None	See Table 3	Present study
**Typosyllis cf pulchra* (Berkeley and Berkeley, 1938)	Polychaete	None	See Table 3	Present study
Ampithoe valida S.I. Smith, 1873	Amphipod	None	See Table 3	Present study
Nuttallia obscurata (Reeve, 1857)	Bivalve mollusc	Varnish clam	Widespread in the harbour on intertidal soft sediment	Larson et al. 2003
Crassostrea gigas (Thunberg, 1793)	Bivalve mollusc	Pacific oyster	Second Narrow and Indian Arm on hard substrates	unpublished observations by GP 2001
Mya arenaria Linnaeus, 1758	Bivalve mollusc	Soft shell clam	Indian Arm on intertidal soft sediment	Horiguchi et al. 2003
Mytilus trossulus Gould, 1850 hybrids with *M. galloprovincialis* Lamarck, 1819 and *M. edulis* Linnaeus, 1758	Bivalve mollusc	Foolish mussel	West Vancouver, North Vancouver floats	Present study
Venerupis philippinarum (A. Adams and Reeve, 1850)	Bivalve mollusc	Japanese littleneck	Port Moody on intertidal soft sediment	Horiguchi et al. 2003
Spartina anglica C.E. Hubbard	Vascular plant	Cordgrass	North Vancouver (Maplewood mud flats); Port Moody (southwest shore); intertidal soft sediment	Williams 1999 in Levings et al. 2002

Figure 1. Location of sampling sites in Burrard Inlet, Vancouver, British Columbia.

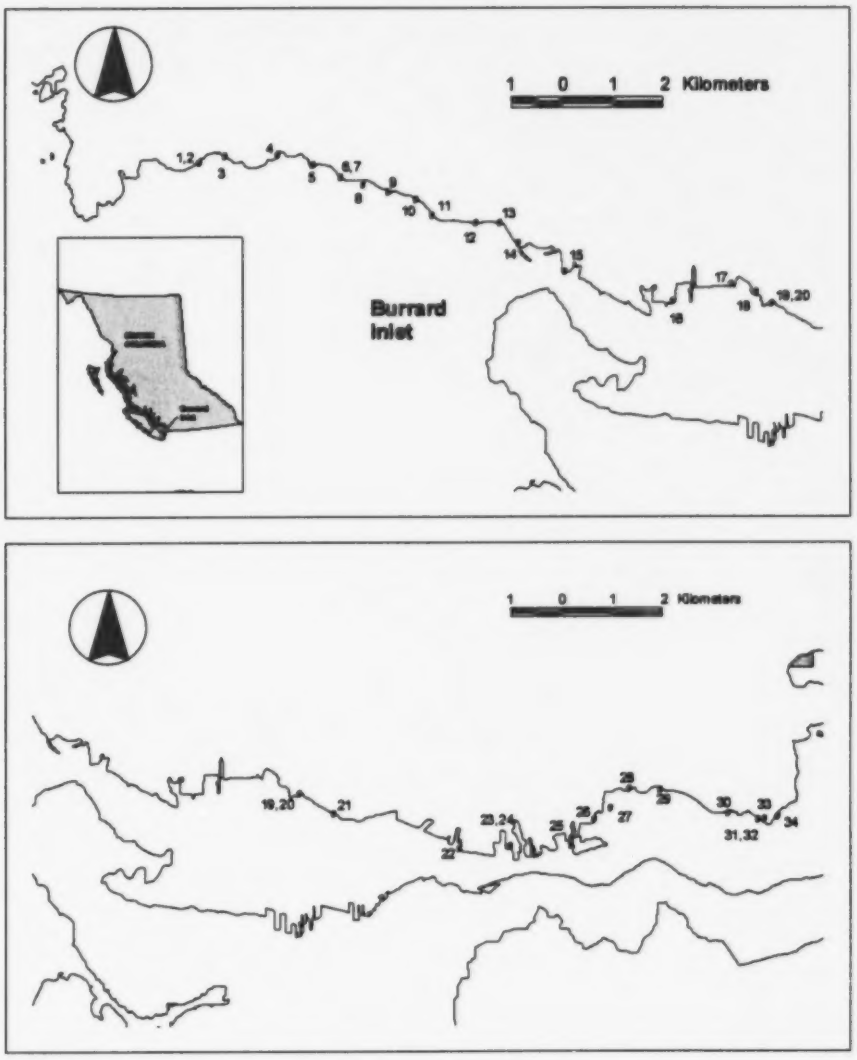

Figure 2. Dendrogram for hierarchical clustering of benthic samples using group-average linking of presence/absence similarities. Group a – qualitative samples from floating structures; Groups b, c, d (intertidal and piling quadrat samples (except Site 2, obtained on a floating dock at West Vancouver Laboratory, West Vancouver)).